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Research Article

Composition of Periphyton Community on Water Hyacinth (*Eichhornia crassipes*): In Analysis of Environmental Characteristics at Ejirin Part of Epe Lagoon in Southwestern Nigeria

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The composition of periphyton community on water hyacinth was investigated at Ejirin, part of Epe Lagoon, in relation to environmental characteristics from December 2012 to May 2013. A total of 14,536 individuals of 104 species belonging to five divisions were identified, with Bacillariophyta (82.69%), Cyanobacteria (10.43%), Chlorophyta (5.63%), and Euglenophyta (1.15%). The total species abundance observed showed a strong correlation with rainfall ($r = 0.745$) and strongly significant correlation with TDS ($r = 0.836^*$; $P > 0.05$). Biochemical oxygen demand value remained (BOD) ≤ 4.8 mg/L while Shannon-Wiener index value remained (H_s) ≤ 1.47. The presence of the following organisms could be used as an indicator of environmentally stressed aquatic ecosystem: euglenoids, blue green algae, *Nitzschia palea*, *Surirella* sp., *Pinnularia* sp., *Gomphonema parvulum*, *Mougeotia* sp., *Spirogyra* sp., *Trachelomonas affinis* (Lemm.), and *T. ensifera Daday; T. gibberosa* Playf. and *Phormidium articulatum*; *Lyngbya intermedia*; *Cymbella ventricosa*; *Eunotia arcus*; *Surirella linearis* and *Closterium parvulum* Nag.

1. Introduction

Water hyacinth (*Eichhornia crassipes*) was introduced into the Nigerian coastal waters in September 1984 from Porto Novo Creek (Benin Republic) and has continued to flourish. Schlorin [1] stated that water hyacinth is a sensitive indicator of environmental status of certain tropical waters. Water hyacinth plant provides suitable surfaces for the development of periphyton as well as aquatic fauna on floating leaves, hanging roots, and creeping stems. According to Egborge [2], water hyacinth harbours a variety of organisms which include algae, rotifers, nematodes, annelids, molluscs, hydracerids, cladocerans, copepod, conchostracans, isopod, amphipods, crabs, and fishes. Organisms such as snails and mayflies affect the periphyton species assemblage, biomass, and productivity [3].

The algae found in water bodies depend on cells, which may either float on the surface or grow on submerged objects, and are divided into two groups, namely, phytoplankton and periphyton [4, 5]. The term "periphyton," coined by Behning and Cooke [6, 7], was derived from two Greek words, "peri," meaning "round," and "phyton," meaning plant. Periphyton has become a universally accepted expression for all organisms that are attached to a submerged substrate and generally dominated by photosynthetic organism which may be unicellular, colonial, or filamentous species from a variety of prokaryotic and eukaryotic phyla. As applied to this work, Wetzel [8] defined periphyton as the micro-"floral" community living attached to the substrate inside water. This microfloral community plays an important role in water bodies, not only by being important primary producers [9, 10] and serving as an energy source for higher trophic level [11], but also by affecting the nutrient turnover [12] and the transfer of nutrients between the benthic and the pelagic zone [13]. Several works on substrate-mediated effect on periphyton biomass and composition have been reported

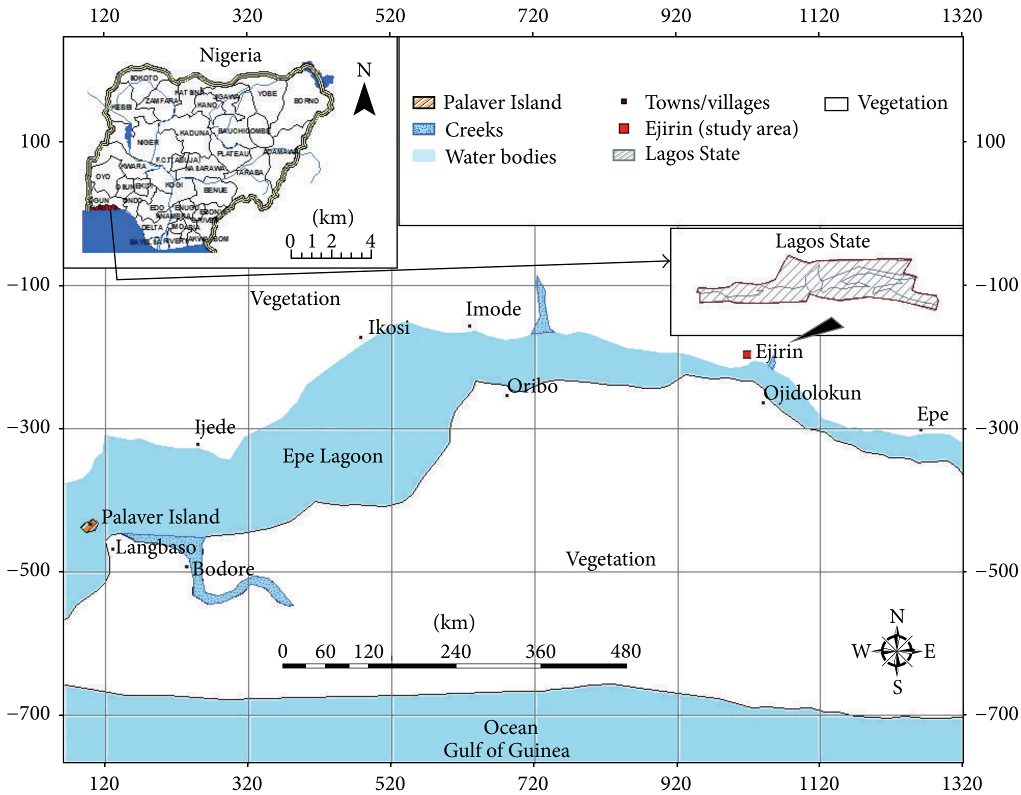

Figure 1: Map of Epe Lagoon showing the study area at Ejirin.

[14, 15] and its usage as an important indicator of the health of aquatic systems [16–18]. These organisms are useful indicator groups for pollution bioassessment due to their sensitivity to pollution. Since the composition of periphyton community on water hyacinth at Ejirin has not been assessed, it is therefore important to document its composition and abundance in relation to environmental characteristics. This study will serve as a source of data background and information on water quality and periphyton abundance and composition.

1.1. Study Area. The study site, Ejirin (Figure 1), located (6°89″N, 3°38″E) is part of Epe Lagoon, freshwater and nontidal lagoon. It is sandwiched between Lekki Lagoon to the east and Lagos Lagoon to the west. It experiences the same hydroclimatic conditions as the rest of southwestern Nigeria such that there are two main seasons (wet and dry). The littoral vegetation found there is dominantly Raffia palm and some dotted mangrove, while on surface water some floating macrophyte like water hyacinth (*Eichhornia crassipes*) dominates. The people there are mainly artisanal fishermen, sand miners, and petty traders.

2. Materials and Methods

2.1. Physicochemical Characteristics. Water samples were collected on each trip between 09:00 and 13:00 and stored in 250 mL well labelled plastic bottles and transported to the laboratory in an ice chest. Surface water temperatures were measured in situ using a mercury-in-glass thermometer and recorded to the nearest 0.1°C. Transparency was determined using 20 cm white painted Secchi disc while pH values were measured using a Graffin digital pH meter. Dissolved oxygen concentration was determined by unmodified Winkler method [19], conductivity was assessed using the meter (Philips PW9505), and chemical oxygen demand and biochemical oxygen demand values were determined using the method described in APHA [20]. Reactive nitrogen, reactive phosphorus, sulphate, and silicate were measured as described by APHA [20]. Rainfall data was obtained from the Federal Meteorological Department, Oshodi, Lagos.

2.2. Determination of Periphyton Biomass. Healthy plants were carefully selected to ensure uniformity in size before putting each into plastic containers with 500 mL of tap water. The attached algae were removed mechanically by shaking vigorously in water as suggested by Foerster and Schlichting [21] and preserved in a well labelled plastic container with 4% unbuffered formalin added to fix the periphyton sample. Another 500 mL container was filled with an unfixed sample for chlorophyll *a* analysis. Chlorophyll *a* was determined by fluorometric method as described by APHA [20].

2.3. Analysis of Biological Characteristics. Periphyton samples were thoroughly investigated using CHA and CHB binocular microscope with a calibrated eye piece, noting all fields. Counting was done using a microtransect drop count, and

Table 1: Status of physicochemical parameters at Ejirin, part of Epe Lagoon, from December 2012 to May 2013.

Parameters	December	January	February	March	April	May	Mean	Standard deviation
Water temp. (°C)	29.3	28.3	29	30.6	29.3	33.1	29.93	1.72
Transparency (cm)	43	57	41.5	38.5	34	31	40.8	9.11
Depth (cm)	25	28	30	27	30	26	27.7	2.07
pH	6.639	6.15	6.22	6.45	6.6	6.5	6.39	0.17
Conductivity (μs/cm)	0.192	0.154	0.2	0.006	0.2	0.35	0.18	0.11
TSS (mg/L)	55	66	170	73	1	1.1	61.01	62.09
TDS (mg/L)	0.65	79	87	141	119	161	97.94	56.95
Rainfall (mm)	13.2	0	28	50.1	165.3	340.8	99.57	132.25
Salinity (‰)	0	0	0	0.01	0	0	0.002	0.004
Nitrate (mg/L)	0.32	0.11	0.08	0.08	0.12	0.07	0.13	0.095
Phosphate (mg/L)	0.78	0.65	0.59	1.08	0.71	0.59	0.73	0.18
Sulphate (mg/L)	1.20	0.80	1.26	1.30	1.21	1.26	1.17	0.19
Silicate (mg/L)	0.40	0.80	0.11	0.05	0.05	0.06	0.25	0.30
Periphyton chl. *a* (mg/L)			0.003	0.001	0.003	0.003	0.0023	0.00096
Biological oxygen demand (mg/L)	4.8	0.4	2	3.7	2.2	0.8	2.32	1.68
Chemical oxygen demand (mg/L)	15	16	20	37	32	32	25.33	9.46
Dissolved oxygen (mg/L)	6.13	10	4.5	5	5.8	6	6.24	1.95

10 drops of periphyton samples were investigated for each month as described by [22]. All organisms, unicels, filaments, and coenobia were counted as one and recorded as per mL. Appropriate texts such as [23–26] (Biggs and Kilroy) were used to aid in the identification of periphyton. Two community structure parameters were used to determine possible response of the periphyton flora to environmental stress. These were as follows.

(i) Shannon-Wiener diversity index (H_s), proposed by Shannon-Wiener in 1963: it is given by

$$H_s = \frac{N \log N - \sum P_i \log P_i}{N}, \tag{1}$$

where H_s is Shannon-Wiener index, N is the total number of individuals in the population, P_i is proportion that the ith species represent the total number of individuals in the sampling space, $\sum$ is summation, and i represents counts denoting ith species ranging from 1 to n.

(ii) Species richness index (d), proposed by Margalef in 1951: it is given by

$$d = S - \frac{1}{\text{In}\, N}, \tag{2}$$

where d is species richness index, S is the number of species in the population, and N is the total number of individuals in species.

2.4. Statistical Analysis. Statistical analysis was carried out with the aid of SPSS (version 17) and PAST (version 3) statistical tools. Correction coefficient [27] was used to evaluate relationship between periphyton abundance and some environmental variables (temperature, salinity, total monthly rainfall, TDS, TSS, transparency, pH, and micronutrients). It is given by Spearman rank correlation:

$$r = 1 - \left[\frac{6\sum D^2}{n(n^2 - 1)}\right], \tag{3}$$

where r is the correlation coefficient, $\sum D^2$ is the sum of squares of difference of the ranks, and n is the number of months.

t-test analysis was carried out to evaluate statistical difference ($P > 0.05$) in seasonal (wet and dry) abundance of periphyton community. Standard deviation and mean analysis were also evaluated.

3. Result

The data for physicochemical features at Ejirin Creek from December 2012 to May 2013 showed seasonal variation as presented in Table 1. Surface water temperature peaked 33.01°C in May and lower value of 28°C in January with a mean value of 30°C. The surface water temperature showed a strong significant correlation with rainfall ($r = 0.855^*$; $P > 0.05$) (Table 3). The surface water pH was acidic throughout the sampling period (pH $\leq$ 6.6) with a mean value of 6.39. Conductivity peaked 0.35 μs/cm in May and lower value of 0.006 μs/cm in March, with a mean value of 0.184 μs/cm. Conductivity showed a strong positive correlation with rainfall ($r = 0.701$) and with periphyton chlorophyll a ($r = 0.506$). Transparency values were high in the dry months and low in the wet months. This corresponds to the rainfall pattern encountered during the study. The water remained fresh throughout the study period with salinity value $S \leq 0.01$‰.

The micronutrients varied throughout the study periods with reactive nitrate (NO_3-N $\leq$ 0.32), reactive phosphate

Table 2: Species abundance distribution of periphyton at Ejirin, part of Epe Lagoon, from December 2012 to May 2013.

Periphyton taxa	December ($CellsmL^{-1}$)	January ($CellsmL^{-1}$)	February ($CellsmL^{-1}$)	March ($CellsmL^{-1}$)	April ($CellsmL^{-1}$)	May ($CellsmL^{-1}$)
Phylum: Cyanophyta						
Class: Cyanophyceae						
Order I: Chroococcales						
Chroococcus major	24				47	
Chroococcus gardneri				23		23
Chroococcus occidentalis				28		
Chroococcus deltoids					51	
Chroococcus mediocris					33	37
Chroococcus mipitanensis						36
Merismopedia punctata Meyen	7					21
Chlorella subsala Lemm.				14		
Chlorogloea gardneri				23		
Cyanothece sp.				14		
Gomphosphaeria sp.				22		
Aphanocapsa conferta					43	32
Anacystis sp.		14				
Aphanothece comasii						22
Aphanothece variabilis		8				
Order II: Nostocales						
Anabaena sp. Bory ex Bornet			42	18	37	46
Order III: Oscillatoriales						
Lyngbya intermedia Agardh ex Gomont		58	179	147	201	187
Phormidium articulatum				42		34
Komvophoron sp.						18
Phylum: Euglenophyta						
Class: Euglenophyceae						
Order I: Euglenales						
Euglena oxyuris var. *charkowiensis*	8			13	8	11
Euglena gracilis Klebs				12		
Phacus orbicularis Hubner				14		
Phacus caudatus Hubner				13		
Phacus triqueter	13					
Trachelomonas affinis (Lemm.)				12		12
Trachelomonas ensifera Daday				9	16	
Trachelomonas gibberosa Playf.				13		13
Phylum: Bacillariophyta						
Class: Bacillariophyceae						
Order I: Centrales						
Aulacoseira granulata var. *angustissima* f. *curvata* Simon	172	41	301	342	407	524
Aulacoseira granulate var. *angustissima* f. *spiralis* O. Mull.	181	101	309	498	587	651

Table 2: Continued.

Periphyton taxa	December (CellsmL^{-1})	January (CellsmL^{-1})	February (CellsmL^{-1})	March (CellsmL^{-1})	April (CellsmL^{-1})	May (CellsmL^{-1})
Aulacoseira islandica subsp. *Helvetica* O. Mull.	98	40	134	192	271	285
Aulacoseira granulata (Ehr.)	189	115	337	414	541	702
Aulacoseira italica (Ehr.)	13	33	103	175	203	198
Hemidiscus cuneiformis		29		35		21
Cyclotella meneghiniana Kütz. ex BrǾ.	72	18			108	67
Cocconeis pediculus Ehr.	48		62	48	98	72
Rhizosolenia longiseta				12	11	
Rhizosolenia hebetata Bail.					14	
Order II: Pennales						
Eunotia arcus Ehr.	72			37	27	37
Diatoma tenuis Bory			117	121	113	67
Cymbella ventricosa Agardh	31	21		24	27	34
Surirella debesi Turpin				24		27
Surirella robusta var. *splendida*						21
Surirella robusta var. *armata*						17
Surirella linearis Turpin	19		47	38	27	31
Synedra acus Ehr.		21				31
Synedra ulna var. *contracta* Ehr.	22		18	21		38
Staurosirella leptostauron						14
Asterionella formosa Hassall		21		207		
Gyrosigma scalproides Hassall					19	
Gyrosigma attenuatum Hassall		16	13			
Gomphonema parvulum Ehr.	21	17		24	36	31
Navicula lanceolata Bory				98		
Navicula pupula Kütz. var. *rectangularis* Grun. Compr.					32	
Navicula radiosa	19		28	52		
Navicula margalithii	23		57	38	37	
Stauroneis anceps						27
Nitzschiaacicularis Kütz.				52	37	33
Nitzschia dissipata		18		28	27	
Nitzschia intermedia	31	31	34	54	42	41
Nitzschia inconspicua	31		32		38	51
Nitzschia closterium					31	32
Nitzschia gracilis			31		29	44
Pinnularia acrosphaeria (Breb.) var. *minor* Kütz.		27		36		
Pinnularia gibba		17	31			
Pseudostaurosira brevistriata		11				
Amphora ovalis Kütz.			47	52		
Epithemia argus var. *longicornis* Grun.				39	19	
Epithemia sorex				47		
Rhopalodia operculata (Ehr.) Müller				21		
Achnanthidium lanceolatum Kütz.	21	16				
Achnanthidium linearis Kütz.		12	27			

Table 2: Continued.

Periphyton taxa	December ($CellsmL^{-1}$)	January ($CellsmL^{-1}$)	February ($CellsmL^{-1}$)	March ($CellsmL^{-1}$)	April ($CellsmL^{-1}$)	May ($CellsmL^{-1}$)
Phylum: Chlorophyta						
Class: Chlorophyceae						
Order I: Chlorococcales						
Ankistrodesmus falcatus Ralfs var. *mirabilis* West f. *longiseta* Nygaard						29
Ankistrodesmus falcatus Ralfs var. *spirilliformis* West				32		
Ankistrodesmus falcatus Ralfs				18		
Ankistrodesmus falcatus Ralfs var. *setiformis* Nygaard f. *brevis* Nygaard				22		
Ankistrodesmus gracilis Corda					21	
Ankistrodesmus braianus					24	
Scenedesmus armatus Chodat	19	23		11	13	
Scenedesmus perforates Meyen			31			
Scenedesmus dispar f. *canobe 2-cellulaire*		11		14	12	22
Scenedesmus quadricauda				11	19	17
Actinastrum Hantzschii Lagerheim				11		
Kirchneriella sp. Schmidle				7		
Tetrastrum stauroeniaeforme		16				
Tetrastrum heteracanthum f. *epine par cellule*					14	13
Selenastrum gracile Reinsch						13
Pediastrum simplex Meyen						17
Pediastrum duplex Meyen				17		
Pediastrum biradiatum var. *longicornutum*				16		
Pediastrum tetras Ralfs				17	11	
Quadrigula closterioides				11		
Crucigenia tetrapedia (Kirch.) West et G.S.				14		17
Crucigenia minima Brunnthaler	14			16		
Order II: Zygnematales						
Spirogyra sp. Link		3	7			
Closterium kutzingii f. *sigmoides*			22	26		
Closterium jenneri Ralfs				21		
Closterium parvulum Nag.				32		
Staurastrum pingue Meyen ex Ralfs					19	18
Staurastrum cyclocanthum var. *ubacanthum vue apicale*	21				13	
Staurodesmus dickiei var. *maximus*						14
Cosmarium sp. Corda ex Ralfs				13		
Cosmarium scottii				18		
Cosmarium trachypleurum						12
Cosmarium sinostegos var. *obstusius*						7
Total species diversity (*S*)	**24**	**26**	**23**	**63**	**41**	**49**
Total species abundance	**1169**	**738**	**2009**	**3490**	**3363**	**3767**

(PO_4-P ≤ 0.78), silicate (SiO_3 ≤ 0.80), and sulphate (≤1.30). Periphyton chlorophyll *a* reached a peak value (0.003 mg/L) recorded in February and April while its lower value (0.001 mg/L) was recorded in March, with a mean value of 0.0023 mg/L. Biochemical oxygen demand reached a peak value (4.8 mg/L) recorded in December and the lowest value (0.4 mg/L) was recorded in January, with a mean value of 2.317 mg/L. Chemical oxygen demand value ranged between 15 mg/L (December) and 37 mg/L (March), with a mean value of 2.31 mg/L. Dissolved oxygen demand (DO) value reached a peak value (10 mg/L) recorded in January and a lower value (4.5 mg/L) was recorded in February, with a mean value of 6.24 mg/L.

The checklist of the periphyton species between December 2012 and May 2013 is presented in Table 2. A total of 14, 536 individuals of 104 species were recorded throughout the study period. The total number of taxa varied from 24 in December to 26 in January, 23 in February, 63 in March, 41 in April, and 49 in May. Diatom populations during both seasons were dominated by 10 centric diatoms and 34 pennate diatoms and a total of 19 species were recorded for Cyanobacteria. Five divisions were recorded with their percentage of occurrence: Bacillariophyta (82.69%), Cyanobacteria (10.43%), Chlorophyta (5.63%), and Euglenophyta (1.15%). The total amount of periphyton abundance shows a strong positive correlation with water temperature ($r = 0.744$), pH ($r = 0.797$), rainfall ($r = 0.745$), and sulphate ($r = 0.707$). It also strongly correlates significantly with TDS ($r = 0.836^*$; $P > 0.05$) and with transparency ($r = -0.886^*$; $P > 0.05$). There was greater species richness during wet months than dry months with a value $d \leq 7.6$. Shannon-Wiener diversity index value was observed to be $H_s \leq 1.47$ (Table 4).

Table 3: Pearson correlation coefficient matrix of water quality indices, total periphyton abundance, and rainfall from December 2012 to May 2013 at Ejirin, part of Epe Lagoon.

Parameters	Total abundance	Rainfall
Rainfall	0.745	1
Water temperature	0.744	0.855*
Transparency	−0.886*	−0.755
pH	0.797	0.65
Conductivity	0.115	0.701
TSS	−0.423	−0.652
TDS	0.836*	0.678
Salinity	0.403	−0.183
Reactive nitrate	−0.533	−0.375
Reactive phosphate	0.247	−0.319
Sulphate	0.707	0.374
Silicate	−0.870*	−0.53
Peri. chlorophyll *a*	−0.566	−0.007
BOD	−0.039	−0.398
COD	0.955**	0.587
DO	−0.597	−0.206

*Correlation is significant at 0.05 level (2-tailed).
**Correlation is significant at 0.01 level (2-tailed).

4. Discussion

The range value of the surface water temperature reported is notable for tropics. The highest water temperature observed in May could be a result of time of collection and heat capacity of water. The positive correlation that exists between rainfall and surface water temperature could explain the possible effect of precipitation on temperature. Nwankwo [28] reported that there are two main seasons in Nigeria: dry season (November–April) and wet season (May–October). The rainy season is ecologically more important in coastal waters and is bimodal in distribution. Floods caused by rainfall enrich the coastal environmental gradients (horizontal and vertical). With this seasonal pattern, it was observed that transparency, total dissolved solids, and total suspended solids increased with the onset of rainfall. The micronutrients concentration level increased as precipitation rate increased probably due to input from settlements and wetlands.

Odum [29] related pH levels to the amount of carbonate present in the water and often considered it an indicator of the aquatic chemical environment. The observed pH value (pH ≤ 6.6) falls within the range reported by Nwankwo and Akinsoji [30] for Epe Lagoon. The pH value could mainly be controlled by freshwater swamp exudates that regulate the acidity of the water body. Change in pH value has a profound effect on the conductivity level of the water. Furthermore, the high value of dissolved oxygen observed in January could be a result of combined photosynthetic activity of the microscopic plants, whereas the low value may be attributed to bacterial degradation of organic matter, which was observed at the onset of precipitation.

Hynes [31] reported that BOD values of 1-2 mg/L or less represent clean water, of 4–7 mg/L represent slightly polluted water, and of more than 8 mg/L represent severe pollution. Therefore based on the above criteria, the site was relatively clean except for December and March where levels of contamination were reported. The Shannon-Wiener index of diversity of 1–3 according to Wilh and Dorris [32] signifies moderately polluted water and above 3 signifies clean water situation. In this regard Shannon-Weiner index in December and March in periphyton community may point towards moderate pollution at this period.

However, the chlorophyll *a* for periphyton community showed a rhythmic pattern with nutrient level mostly reactive nitrate. This may explain the importance of reactive nitrate to periphyton community. The periphyton abundance in the wet months differs significantly with that of dry months ($t^* = 8.799$; $P > 0.05$). This could be a result of favourable conditions during this time that resulted in the multiplication of algal cell and additional input of pennate forms by the floods. The algal spectrum observed shows that diatoms were the dominant species in periphyton community.

Bowker and Denny [33] reported the limited growth of attached diatoms in the dry season and the rapid growth of macrophyte tissue. This may explain why more species were observed on macrophyte tissues in the wet months. Some of the algae that were common members of the plankton but

Table 4: Biological indices parameters at Ejirin, part of Epe Lagoon, from December 2012 to May 2013.

Periphyton taxa	December	January	February	March	April	May
Total species diversity (S)	24	26	23	63	41	49
Total abundance (N) cellsmL^{-1}	1169	738	2009	3490	3363	3767
Shannon-Wiener index (H_s)	1.17	1.28	1.15	1.47	1.26	1.27
Margalef's index (d)	3.26	3.79	2.89	7.6	4.93	5.83

were found in periphyton community were often trapped by the roots of the plant, like the centric diatoms. However, the centric diatoms found in the periphyton community were transit visitor caught up by the mesh formed of the water hyacinth roots.

The observations that diatoms dominate the periphyton community on water hyacinth confirm earlier reports [34, 35] that diatoms were more abundant in the algal spectrum of the Lagos Lagoon complex.

Round [36] observed the abundance of *Eunotia* sp. on *Lemna* roots whereas Bowker and Denny [33] reported the dominance of *Achnanthes* and *Cocconeis* sp. on the roots and leaves of *Lemna,* respectively. *Cocconeis pediculus* Ehr. and *Achnanthidium* sp. were only found in the periphyton community with *Cocconeis* occurring all through the months suggesting a strong coexistence. *Cocconeis pediculus* Ehr. occurred in a range of conditions from clean to moderately enriched to much enriched waters. Its presence and others (euglenoids; blue green algae; *Nitzschia palea*; *Surirella* sp.; *Pinnularia* sp.; *Gomphonema parvulum*; *Mougeotia* sp.; *Spirogyra* sp.; *Trachelomonas affinis* (Lemm.); *T. ensifera* Daday; *T. gibberosa* Playf.; *Phormidium articulatum; Lyngbya intermedia; Cymbella ventricosa; Eunotia arcus; Surirella linearis; Asterionella formosa* Hassall; *N. acicularis; Amphora ovalis* Kütz.; *Ankistrodesmus falcatus; Scenedesmus armatus* Chodat; and *Closterium parvulum* Nag.) may suggest pollution by organic materials.

The abundance of periphyton species on the water hyacinth may be given a second thought to enhance the aquaculture production in the area. A high species level for blue green algae and euglenoids in the periphyton community may reveal its suitability in monitoring environmental stress in coastal waters.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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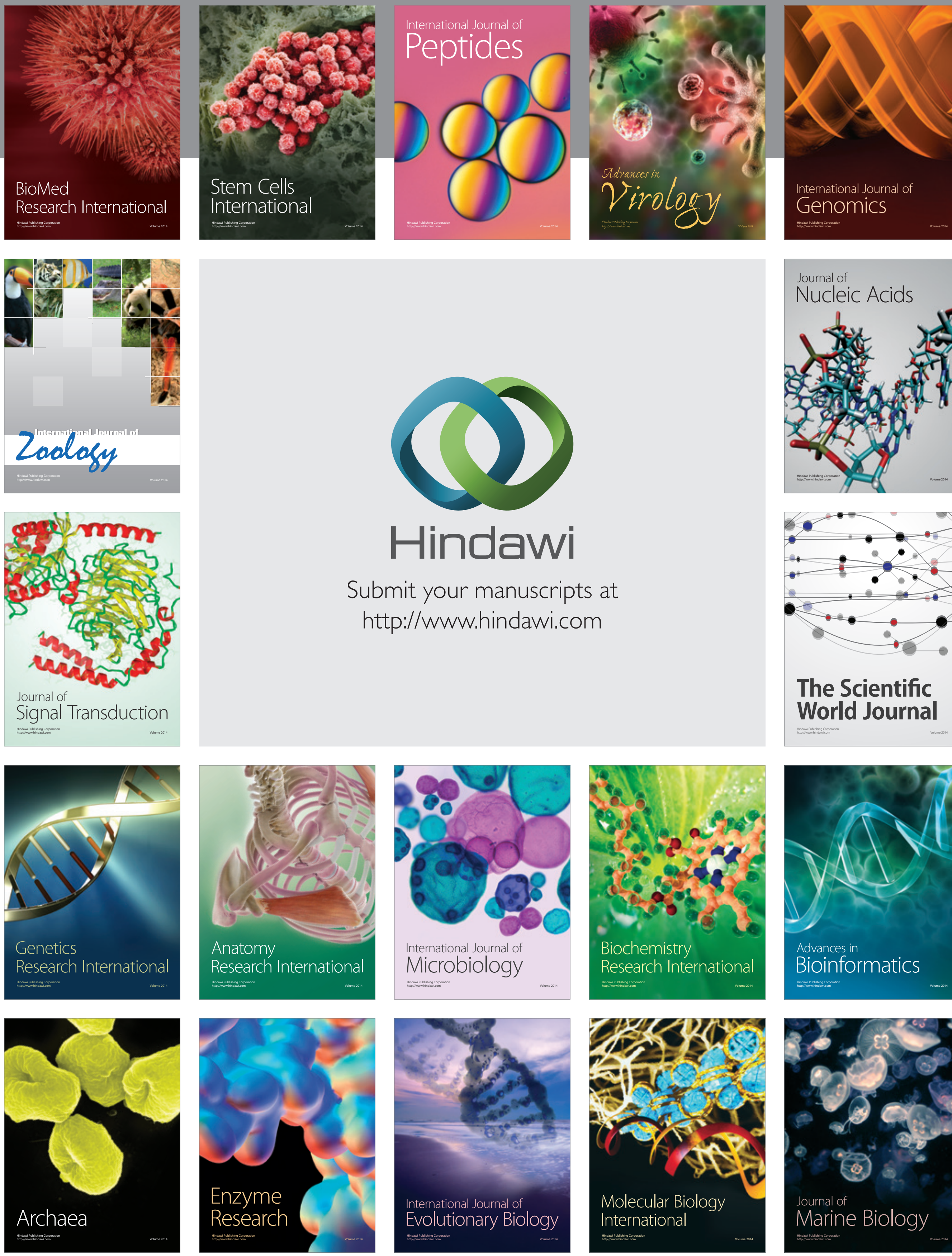
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